Trace Minerals Functions in Ruminant Animals

Subjects: Agriculture, Dairy & Animal Science

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Trace minerals play an important role in animal health and productivity. They are involved also in many physiological activities, and their deficiency causes a variety of pathological problems and metabolic defects, reducing consequently the animal productivity.

Keywords: trace element ; mineral deficiency ; mineral toxicity

1. Introduction

The arid lands of Africa and Asia are under pressure due to global warming, which is affecting the rangelands' productivity and the feed resources for livestock [1], especially the camel, which is the most adapted domestic animal to such ecosystems. As a result of these changes, the trend for camel farmers is to modify their production system based on herd mobility to primarily settled, semi-intensive systems [2][3]. For the livestock remaining under extensive systems, wide seasonal variations affect the quality and quantity of the feedstuffs and consequently the nutritional status of the grazing animals, as well as their health and productivity directly and indirectly [4][5][6][7][8][9][10]. Under more intensive systems, camel feeding is progressively becoming dependent on supplements as a means of meeting the nutrient requirements [11]. In this context, the feeding system is changing from a highly diversified diet (with high variability in nutritive value and grazed ecosystems) to a standard diet (typically alfalfa + occasionally barley + concentrates) [3]. Such diets do not necessarily cover the nutrient requirements, including trace minerals [12], leading to low growth or low milk productivity [13] [14].

Trace minerals contribute to the camels' health and productivity, especially when they become a limiting factor in the diet [15]. In herbivores, trace minerals play a pivotal role in many physiological activities, and their deficiency causes a variety of pathological problems and metabolic disorders [16][17][18][19], including in camels [20]. Infertility, non-infectious abortion, anemia and metabolic diseases are some of the main clinical signs of deficiencies and abnormalities [21][22]. A few scientific studies have shown some evidence of the sensitivity of camels to trace mineral disorders, resulting in either deficiency or toxicity in the same way as in other ruminants [23]. Faye et al. [24], Faye and Bengoumi [23] and Liu et al. [25] have reported several incidences of clinical mineral deficiencies in camels being underestimated because the signs of subclinical deficiencies may remain undetected for long periods. Regarding toxicity, the evidence is even rarer, although some cases of selenosis have been described [26], as well as fluorosis [27].

Under field conditions, the trace mineral status of animals in terms of deficiency, adequate supply or excess are difficult to assess. Different substrates such as urine, feces, and hair can be convenient for investigating the mineral status of animals [15], but blood remains the most common biological material used in practice to detect a deficiency or toxicity under field conditions.

2. General Overview of Trace Minerals Functions

Factors such as the level of nutrition, mineral availability and mineral utilization affect the production and reproductive ability of both males and females in ruminant animals [19]. The effect of a specific mineral on metabolism can be observed in the four stages that characterize the development of deficiency. The first stage, the initial depletion, is restricted to changes in the metabolism of the element itself (the adjustment of absorption and upregulation of carriers). The second stage, the compensated metabolic phase, is characterized by changes in the element-dependent function; this can be compensated for by another independent system unless stress is imposed. The third stage, metabolic deficiency, involves changes in the major metabolic pathways (nucleic acids, proteins, carbohydrates, and fats). The fourth stage, clinical deficiency, involves clinical symptoms, disease and eventually death [28].

Because the diversity of proteins and enzymes containing Zn, Cu, Mn, Co, I and Se, these trace minerals are essential for a wide variety of physiological processes regulating growth, production, reproduction, and health. Deficiencies in these

nutrients consequently lead to reduce performance, and dairy cattle diets are therefore formulated with trace mineral supplements to prevent these deficiencies as mentioned in many papers [29][30][31][32][33][34][35][36][37][38][39][40][41]. For example, cobalt is a main component of vitamin B12 (cyanocobalamin) and plays an important role in microorganisms of the rumen [42] while iodine is involved in the synthesis of thyroid hormones [43].

One of the most important roles of trace elements is their contribution to the antioxidative function. This role is particularly efficient in stressful situations [30][32][44]. Oxidation is a normal process that produces free radicals, and the antioxidant system is activated to neutralize these free radicals before they cause cellular damage. Zn, Cu and Mn are integral components of this system due to their presence in superoxide dismutase (SOD), which reduces the free radical superoxide to hydrogen peroxide. Selenium is a component of glutathione peroxidase (GSHpx), which then converts hydrogen peroxide into water. Oxidative stress is an imbalance between antioxidants and oxidants in favor of the latter [45].

In a healthy animal, the antioxidant system reduces free radicals as several agents are produced to prevent them from damaging cells and metabolites. However, under severe stress, the rate of free radical production can exceed the rate of free radical neutralization by the antioxidant system, and this can lead to oxidative damage to the lipids, carbohydrates and proteins within cells [44]. Examples of such times of oxidative stress include calving, infection and heat stress [44][46]. Higher-producing cows have also been shown to have greater concentrations of oxidatively damaged lipids than lower-producing cows [47].

During late gestation, the immune function is weakened, and dairy cows have a decreased capacity to stay in good health [48]. Oxidative stress, non-esterified fatty acids, ketones, negative energy balance and inadequate calcium status are the main factors believed to be responsible for this immunosuppression [49]. The health disorders associated with oxidative stress include mastitis, retained fetal membranes and udder edema. The trace minerals with an antioxidant function include Se, Cu, Zn, Mn and Fe. Some diets have a role in directly quenching free radicals [50]. Minimizing health disorders during late gestation is economically advantageous because diseases are costly, not only in terms of treatment costs, but also because of the subsequent decreases in lactation performance and reproduction, the increased risk for additional health disorders and the decreased market value and productive life [51].

Thus, a deficit of minerals could be associated with different situations of stress, notably during seasonal changes, leading for example to a decrease in serum concentrations of copper (Cu), Co and Zn, as it has been reported in grazing dairy cattle in western Sudan during the late dry season [52]. Similar seasonal changes in mineral profiles (Cu, Zn, Mn and Co) were detected in the serum samples of grazing Jordanian sheep [53] and cattle [54]. Another study on the mineral and vitamin status of sheep in Syria, Jordan and Turkey, in which blood samples were collected from 18 sites, indicated a decrease in Cu and Zn levels at the end of the winter season [55].

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